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# Preoperative transcutaneous electrical nerve stimulation for localizing superficial nerve paths

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**Summary** During surgery, peripheral nerves are often seen to follow unpredictable paths because of previous surgeries and/or compression caused by a tumor. Iatrogenic nerve injury is a serious complication that must be avoided, and preoperative evaluation of nerve paths is important for preventing it. In this study, transcutaneous electrical nerve stimulation (TENS) was used for an in-depth analysis of peripheral nerve paths.

This study included 27 patients who underwent the TENS procedure to evaluate the peripheral nerve path (17 males and 10 females; mean age: 59.9 years, range: 18—83 years) of each patient preoperatively. An electrode pen coupled to an electrical nerve stimulator was used for superficial nerve mapping. The TENS procedure was performed on patients' major peripheral nerves that passed close to the surgical field of tumor resection or trauma surgery, and intraoperative damage to those nerves was apprehensive.

The paths of the target nerve were detected in most patients preoperatively. The nerve paths of 26 patients were precisely under the markings drawn preoperatively. The nerve path of one patient substantially differed from the preoperative markings with numbness at the surgical region.

During surgery, the nerve paths could be accurately mapped preoperatively using the TENS procedure as confirmed by direct visualization of the nerve. This stimulation device is easy to use and offers highly accurate mapping of nerves for surgical planning without major complications. The authors conclude that TENS is a useful tool for noninvasive nerve localization and makes tumor resection a safe and smooth procedure.


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## Introduction

It is critical to determine an accurate localization of superficial nerve paths preoperatively to reduce iatrogenic nerve injury risk intraoperatively, where certain nerves are more prone to such injury.[1]

In a retrospective study of 612 patients of iatrogenic peripheral nerve damage in the trunk or limbs, Khan and Birch reported that four nerves were at a considerably higher risk from damage because of incision and dissection: the spinal accessory nerve at the posterior triangle of the neck, common peroneal nerve at the knee, and median and ulnar nerves at the wrist.[1] The temporal branch of the facial nerve is particularly vulnerable to injury during facial surgical procedures requiring incision in the temporoparietal area[2] because the nerve path over the zygomatic arch is superficial and variable among patients.[3]

Historically, superficial nerve path evaluation was first developed for effective nerve block. For approximately a century after the first nerve block in 1885, the injection site was chosen according to anatomical landmarks.[4] However, these landmarks vary among patients, and locating an appropriate injection site by needle exploration is invasive and may result in nerve injury.[5] In 1978, La Grange et al. detected the subclavian artery using ultrasound (US) to provide an anatomical landmark for brachial plexus nerve block.[6] In 1994, Kapral et al. used this US-guided supraclavicular approach for regional anesthesia of the brachial plexus. With time, this nerve localization method for anesthetic injection has been further improved by technological refinements in US.[7] However, peripheral nerves can be difficult to differentiate from adjacent background structures; the technique requires a certain amount of training and deep knowledge of the distinguishing features of nerves to detect them correctly.[8]

Transcutaneous electrical nerve stimulation (TENS) is a noninvasive technique that localizes target nerves by probing the skin with a pen electrode. Unlike US, TENS can directly stimulate nerves and precisely evaluate nerve paths without specific training. Furthermore, TENS can distinguish motor from sensory nerves objectively by the nature of the patient response (i.e., muscle contraction or sensation). In 2002, Urmey reported a pen-type TENS system; In 2011, Usui et al. used this system to identify the lateral femoral cutaneous nerve for nerve block.[5,9]

In this study, a pen-type TENS system was used to identify superficial nerve paths before tumor resection or trauma surgery. The device enabled mapping of nerve paths and proved particularly useful for locating nerves in the region of benign tumor dissection.

## Patients and methods

The peripheral nerve paths of 27 patients were evaluated using the TENS procedure (17 males and 10 females; mean age: 59.9 years; range: 18—83 years) preoperatively between September 2011 and June 2013 at our institution. Patients were selected according to the risk of intraoperative damage to superficial peripheral nerves, and most surgeries were performed for tumor removal, including parotid gland tumors, schwannoma, enlarged lymph nodes, and lipoma.

### Peripheral nerve localization using TENS

An electrode pen coupled to an electrical nerve stimulator (Stimuplex NHS12; B. Braun http://www.bbraun.com/cps/rde/xchg/bbraun-com/hs.xsl/products.html?prid=PRID00001835) was used for superficial nerve mapping with grounding to either the right or left forearm. To elicit a motor response or paresthesia, the initial stimulating current was set at 4 mA and then decreased to the minimum current required. All electrical stimuli were delivered at 2 Hz and a 1-ms pulse width. Major anatomical landmarks were used for gross localization, followed by careful manipulation of the electrode pen over the skin surface for fine localization. The pen pressure on the skin should be gentle because excessive pressure can shift the nerve position (Figure 1). Once the target nerve was identified at one position, its path was tracked by repeating this procedure at 1-cm intervals (Supplemental Video 1).

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.bjps.2015.08.018.

## Results

The TENS method was used to localize and map the facial nerve path in 17 patients; accessory nerve in seven; proper palmar digital nerve in two; and median, medial brachial cutaneous, superficial branch of the radial, and lateral cutaneous nerves of the forearm in one patient each. The mapping accuracy was intraoperatively confirmed in cases where the nerve was exposed, including eight facial, two accessory, two proper palmar digital, one medial brachial cutaneous, and one ramus superficial branch of the radial nerve. These evaluated nerves were precisely under the path markings drawn preoperatively (Supplemental Video 2). However, only one patient had a substantially different nerve path from the preoperative markings with numbness at the surgical region resulting from a previous operation.

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.bjps.2015.08.018.

Three typical cases are described in detail next.

### Case 1

A 61-year-old man was scheduled for left auxiliary subcutaneous tumor removal first diagnosed 2 years earlier. At the time of surgery, Tinel's sign was positive with paresthesia detected in the middle and ring fingers.

It was suspected that the tumor was a schwannoma derived from the median nerve. Using the TENS method, the median nerve at the distal edge of the tumor was identified. However, no response to stimulation directly over the tumor site was obtained; therefore, it was suspected that the median nerve passed under the tumor. The medial brachial cutaneous nerve could also be detected by stimulating the skin over the tumor site, suggesting that this nerve passed above the tumor. Contraction of the dominant target muscles identified the median nerve, and numbness over the dominant dermatomes identified the median brachial cutaneous nerve. During surgery, the